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ABSTRACT

Although many people in education are intimidated by the use of computer-based instruction (CBI), others are committed to exploiting the opportunities it provides. Three areas comprise CBI: instruction about computers, instruction by computers, and instruction using computers; the first two areas have received the most attention. (1) Attention to instruction about computers, or computer literacy, has continued to grow rapidly since the early 1970's, and in the future computing teachers will be increasingly in demand. (2) Although the most successful type of instruction by computer thus far has been drill and practice, the goal of using computerized tutorials and tutorial dialogs to increase individualized instruction deserves continued consideration. (3) Similarly, although instruction using computers has been slow to develop, the computer's potential for testing and for creating individualized problem-solving environments should continue to be explored. In Oregon and elsewhere, the following computer-related issues currently confront the education community: (1) the provision of experiemental settings to test the uses of computers in education, (2) student equity in access to computers, (3) software quality, (4) software piracy, (5) the uses of computers for learning outside the school, and (6) certification standards for computing teachers. With careful planning, CBI offers the opportunity to excel in education. (JBM)

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Opportunities and Issues in Computer Based Instruction

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Introduction

We all know that we are in the midst of a scientific and technological revolution. Members of the press and the scientific community have been vying with each other to capture in print the magnitude of what is occurring. One statement that is a favorite of mine is:

> If the automobile industry had accomplished in the last 20 years what the computer industry has, a Rolls Royce would cost $2.95 and would get 2,500,000 miles per gallon.

Despite the appearance of hyperbole, this statement is reasonably accurate. Despite all the rhetoric, there is considerable substance to what is now taking place.

"Order of magnitude" seems to be a notion for describing what is going on. Briefly, an improvement in order of magnitiude of some value is a replacement of that value by its square. An order of magnitude increase in 10 is 100. The opposite is true for decreases in order of magnitude. If it takes 100 days to go from San Francisco to New York, an order of magnitude decrease in travel time would reduce it to 10 days.

Thanks to the development of the steam engine during the 18th century our efficiency in accomplishing physical work increased considerably. By enhancing the power of what was basically a tool for the hand, we brought about the Industrial Revolution. As a result, the proportion of the labor force required to grow our food declined from well over 50 percent of the population to less than 5 percent. Coach travel, which proceeded at a rate of 3-4 miles per hour, was replaced by railway travel at 40-50 miles per hour. These effects of two to three orders of magnitude are characteristic of the Industrial Revolution.

Today's electronic, stored-program computer was developed in the mid-1940's and integrated circuits (computer "chips") were developed in the mid-1950's. In concert with a few other developments, such as LSI (Large Scale Integrated) circuits, which increased the number of components on a chip from about 10 to more than 10,000, we were, in a span of about 20 years, able to increase our computational capabilities by about 6 orders of magnitude, compared to the perhaps 1 order of magnitude increase over the previous 2,500 years. Based on VLSI (Very Large Scale Integrated) circuits and what some people refer to as ILSI (Incredibly Large Scale Integrated)

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circuits, we should accomplish another 5 or 6 orders of magnitude of improvement in our computing power in the next 15 years. By the turn of the century, then, we should accomplish a 12 order of magnitude improvement in what is essentially a tool for the mind. When faced with the task of indentifying and describing the implications of this development, the imagination understandably boggles.

It should be emphasized that it is not just the imagination that boggles in the face of these developments. There are many people who find the electronics revolution to be, frankly, revolting. Some of these people are teachers and school administrators. Their attitude is understandable. Having mastered at some cost the standard school technologies of blackboards, lectures, laboratories, textbooks, budgets, daily attendance accounting, parent conferences, and all the rest, they are now confronted with unfamiliar devices that promise to undo or at least fundamentally alter everything they have learned. That these devices should create both excitement and concern among the educational community is not surprising.

On the other hand, many school people are deeply committed to the business of education and want to do as well as possible within constraints over which they exercise little control. The result has been a well noted buy-now plan-later approach to computers in education. Pressured from all sides to "do something about computers" educators have rushed to wheel as many computers as possible into the schools in the hope that appropriate uses and applications will flow in their wake. In the light of all this activity, it may be appropriate to pause briefly and take a little perspective on what is happening. What, for instance, are the opportunities and what are a few of the issues that must be resolved?

Opportunities

Computer-Based Instruction (CBI) is a commonly used term for describing all the possible uses of computers in instruction. There seem to be three components of CBI: instruction about computers, instruction by computers, and instruction using computers. All three areas are important. Most attention has been given to the first two.

1. Instruction about Computers

Instruction about computers usually comes under the heading of computer literacy. Unfortunately, there is considerable confusion about what computer literacy means. The term came into prominence via an article in 1972 by Arthur Luehrmann. The article suggested that computer programming was a form of literacy just as reading and writing spoken language are and that future generations, as well as our own, ought to become computer literate. This was a clean, straightforward approach. Computer literacy meant being able to program a computer, and even if there remained some serious questions about what should be done to attain it, at least we had a reasonably firm foundation to build on.

There quickly arose considerable resistance, however, to the notion that computer literacy must necessarily involve computer programming. There are both academic and practical reasons for these objections. In the first place, the need for computer programming just does not yet seem as universal as the need for other kinds of literacy. In the second place, if we are going to teach computer literacy in the schools, who is going to teach it? We did not have a sufficient cadre of computing teachers in 1972 and, despite substantial improvements, we still do not in 1984.

However we decide to define computer literacy, the need to teach about computers remains. Students in our elementary schools can learn to program computers, and many of our secondary school students need to. All our students need some knowledge about how to deal with the word processors, spread sheets, data base systems, and other applications of computers they will encounter in their future. Moreover, they need some foundations in computers so that as citizens of the technological age they will know what credibility to assign to the information that comes from computers and how to treat it.

In any event, the opportunities for teaching about computers are increasing. In the computer business, it is customary to speak of a "rule of two." This rule refers to the developments in computer technology mentioned above. Roughly, every two years the power of available computers doubles and their cost is cut in half. There seems to be another rule of two in the use of computers in education. In Fall 1980 there were 31,000 microcomputers available in the nation's classrooms. This number increased to 96,000 in the spring of 1982. The estimated number for fall 1983 is 250,000. These increases suggest a doubling every twelve months.

This expansion has been primarily funded by allocating about a third of Chapter Two revenue sharing funds to it. The yearly doubling in acquisition rate cannot, then, be sustained forever. However, if we permit one more doubling to an annual acquisition rate of about 250,000 units annually then by about 1988 there will be sufficient computers in the nation's elementary and secondary schools to allow every student ten minutes of computer use every day. Of course the doubling may not stop here.

It is likely, then, that there will be enough computers in schools to satisfy our needs for computer literacy--and more. What about the teachers we need? Currently across the United States, 26 percent of all mathematics teaching positions are filled by teachers who are not certified or who have only temporary credentials to teach mathematics. Among newly employed

mathematics and science teachers, about half lack credentials in the teaching of mathematics and science. A survey of 600 colleges and universities with teacher training programs revealed declines in the number of science and mathematics teachers being prepared of 64 and 78 percent respectively over the last ten years. Moreover, those already in the profession are leaving.

If these are the statistics for mathematics and science teachers, what can we expect for computing teachers? In the schools themselves surveys show that 36 percent of the computer usage in elementary schools is for teaching about computers. Comparable figures in junior high school and high school are 40 percent and 88 percent respectively. Again, where are the teachers going to come from?

There is a possibility here that computer literacy may be as much a solution as a problem. We may be saved by the very ubiquity of microcomputers. A great many people are being exposed to computer programming--mostly BASIC, but LOGO and Pascal are also evident in the surveys--and the representation of teachers among these people appears to be higher than among other occupational groups. Despite early expectations to the contrary, it does not require mathematical or scientific sophistication to learn computer programming. Moreover, there are plenty of significant computer applications outside of mathematics and science. As soon as teachers from better-supplied disciplines discover these facts, we may come up with the numbers of computing teachers that we need.

2. Instruction by Computer

Computers can be used to teach. After more than 25 years of research and development publications to this effect, this statement should not be news. The first evaluation study I am aware of is dated 1956. The first survey of computers used to teach appears to be one by Vinsonhaler and Bass and was published in 1972. These authors were able to find 10 major evaluations of computers used to teach. The evaluations involved more than 10,000 student participants, and they incorporated 34 separate studies. Thirty of the 34 studies showed positive results, and the median increase in student achievement across the studies was 40 percent. More recently, Orlansky and String published in 1979 a major survey on the cost-effectiveness of computers used in military training. These authors reported that positive results had been obtained in 40 of 44 cases and that the median student time saved in reaching established levels of achievement was 32 percent. In 1983 Kulik, Bangert, and Williams reported that the use of computers in secondary schools had raised student scores by approximately .32 standard deviations. Other surveys have been equally promising.

This is not to suggest that computers used to teach always succeed. Vinsonhaler and Bass found one instance in which there was a 40 percent decrease in student achievement. Orlansky and String report another study in which it took 31 percent more time to teach students using a computer than without one. The point is that when an honest effort is made to do a thing right, the results are usually positive and sometimes spectacularly so. We have a long way to go, but so far so good.

The techniques for using computers to teach may be divided into three areas: drill and practice, tutorial, and tutorial dialogue. These are Patrick Suppes' categories and they seem to have held up fairly well over time.

Dexter Fletcher

Drill and practice is doubtless one of the more regretable terms in instruction, evoking images of the classroom as a sweat-shop and attracting the ire of those who want to use computers to create a rich and friendly learning environment for intellectual exploration and discovery in the classroom. The problem is that it works. The Vinsonhaler and Bass survey was limited to one approach in using computers to teach--drill and practice. Some studies of computers used to teach handicapped students showed not only that 10 minutes of daily drill and practice could increase end-of-year achievement by a factor of 3 among some populations, but that the achievement of individual students could be directly, tightly, and solely tied to the amount of time they spent on the computers. Moreover, it appears that students enjoy drill and practice given by computers--as long as it is not overdone. Forty minutes a day with no more than 20 minutes spent on any one drill and practice program seems to work well among elementary school students. Finally, drill and practice is not just a matter of throwing items at students. There are some deep and sophisticated techniques that may be used to decide how many items of what sort should be given to which (individual) students at their separate levels of mastery.

Tutorial techniques in instruction by computer seem to be the least promising. These techniques use the computer as a very large and sometimes very intricate programmed textbook. To an extent they use the computer as an electronic page turner. Computer implementations of this approach could probably be pursued in a book--although the book might have to be carried around in a wheelbarrow. Nonetheless it remains one of the most common, easily produced, and frequently implemented approaches, and it is best supported by the "authoring" languages for instruction by computers. However, there is a strong consensus among those experienced in the business that these intrinsic programming approaches work relatively less well than others. Notably the approach has been successfully carried out, but its success has been less reliable than that of other approaches.

Tutorial dialogue approaches grew out of the observation that the best technology for instruction is probably a log. Put Mark Hopkins on one end of the log and one (and only one) student on the other end and you get an instructional setting that is just about ideal. Even in the midst of the Northwest logging industries, this technology may be too expensive to implement. However, if we can incorporate in a computer the capabilities of an expert tutor, we may arrive at something more practicable. Computers are both very good at this and very bad. Consider the following sentence:

The man the dog the girl owned bit died.

This is a difficult sentence for us to parse. Yet, a computer could very quickly discern, after diving into its recursive routines for processing nested constructions, that there was a dog that was owned by a girl, that the dog bit a man, and that the man subsequently died. Next consider the following example:

What was Charles Dickens' telephone number?

A computer would most probably search the attributes it had associated with Charles Dickens looking for his telephone number. Presumably none will be found. A more intelligent approach would be to notice that telephones were not used until after Dickens' lifetime and to report this fact without even bothering to search attribute lists. It is a real problem to devise a computer program that not only commands a great deal of information, but knows when to apply it. This, however, is what an expert tutor must do, and what we must do in tutorial dialogues. We have made considerable progress in providing what Suppes described as an Aristotle for every Alexander, but we have a long way to go.

Tutorial dialogue represents a major technological opportunity for instruction by computers, but it will be a decade or two before it will be generally available to students. Nonetheless it is at the heart of what we want to accomplish in instruction by computers. The important feature of books was that they made widely and relatively inexpensively available to a wide audience the content of great teaching. Now as Victor Bunderson has pointed out, we have a device that can make both the content and the interactions of great teaching widely available. This accomplishment will come through the development of tutorial dialogues.

Much has been said recently about achieving excellence in American education. However, most rules of two seem impractical here. One way to improve American education would be to double teachers' salaries. Presumably we would attract more good people to the profession, or at the least we would stop losing good people to industry. However, there will have to be dramatic changes in school policy before this change can be accomplished. It might also be possible to double the school year, but this would on the average allow students only 5 days off from school throughout the year--weekends would be abolished. Another way to improve education would be to double the school day from approximately 5 1/2 hours to 10. Some countries support school days of this length, but it is doubtful that we could here.

Finally, however, we might be able to increase the amount of academic learning time within the school day. As it is now, students average 2-4 minutes of individualized academic learning time during the school day. Although we have much to learn about individualization, instruction by computer may support individualized techniques that are simply beyond human capabilities to deliver (in real time). Providing 8 minutes a day of individualized instruction by computer--in some, not every--subject area appears to be within our reach. Perhaps we should set this as a goal. At least it is an opportunity to consider.

3. Instruction Using Computers

Few notions about the use of computers in instruction have been as prevalent as the idea that they should become tools for teachers. This area includes the use of computers to help manage instructional resources, manage student progress, assist in administration, give tests, and control simulations. Research and development in this area have been disappointingly sparse. In some cases, we have rushed into practice what is still poorly understood. The Navy has established a system near Memphis, Tennessee, that manages the training progress of more than 9,000 students a day, but the management procedures used are primitive.

In other cases, we have been slow to implement the obvious. Administrative packages for school administrators have been very slow in coming. We should expect and probably insist on major improvements in these two areas in the near future.

However, research and development in computers used as tools for testing have enjoyed considerable investment. Thanks to optical sense readers and early work to interface them to computers, it is now possible to reduce much of the administrative burden of testing. Costs and time investments for statewide competency testing could be substantially reduced by giving the tests on microcomputers and transferring the test files to a central system for grading and record keeping. Even if tests are administered in a paper and pencil format, computer banks of calibrated items might be used to construct a large number of different but parallel tests for assessing competency and/or mastery in given subject matters.

The most dramatic possibility in the use of computers to test is the development of items that can only be given by computer and that will tap areas of cognition that so far have proven inaccessible to paper and pencil format. Nothing can be so important to the development of a scientific area as a major improvement in its instrumentation, and this is a serious promise of computers used in testing. As far as school practice is concerned, one can imagine compiling a profile on each student that not only reports on current mastery of school subjects but supplies a description of cognitive style, preferred modes on information presentation, estimates of time to mastery under different instructional prescription, etc. The profile could then be used by the classroom teacher in managing the student's progress through the variety of school subjects and the variety of available presentation media.

Finally, it may be possible to use computers as tools to create a problem-solving environment. In this approach, computers provide a source of problem descriptions and become a resource for student problem-solving efforts. The computer serves as an advisor and a coach for students, an observer and reporter for classroom teachers, and a record keeper for all. Students are put into the problem-solving decision environment, or "microworld," of scientists, inventors, artists, statesmen, jurists, etc. Through simulation and reactive environments, students access the same background data, current events, laboratory equipment, tools, etc. available to the participants in significant events. Distinctions between subject matters might disappear as students learn and use basic skills in an integrated fashion to solve the problems. The essential point in these environments is that for all subject domains, students learn material in order to solve problems intended to engage their interest and attention.

Current Issues

Among the states, Oregon is unusual in its support for education. This was noted in Pierce and Hagstrom's Book of America and is corroborated by data from the U.S. Bureau of Economic Analysis and the National Center for Educational Statistics. For example, in 1980 per capita income in Oregon was $9,317, making it 27th in the nation. However, the expenditure per pupil in the 1979-1980 school year was $3,104, 5th in the nation. These data are typical of Oregon. In 1970 the state ranked 25th in per capita income and 6th in per pupil expenditure. An implication of these data is that, among the states Oregon's support of education is traditionally very strong, but that increases in support relative to what may be done by other states are unlikely.

However, it is possible that all states may increase their support of education relative to other state expenditures and objectives. Public opinion polls show that parents are willing to pay more for education provided they get quality in return. If increases occur, Oregon's support may also rise. Right now, however, the state should take pride in its traditionally strong support of education and not expect many changes up or down in the near future. Most likely, then, the resources to bring about the opportunities offered by computers will have to come from within existing levels of support. Nonetheless, there are issues to be faced by the education community. Six of these, by no means a comprehensive set, are discussed here.

1. Experimental Settings

Research and development must address two major issues in the use of computers in instruction. First, we need to learn better how to design materials for computer presentation. For instance we know that we can use computers to teach, but we need to learn much more about how to use computers to teach. There is a world of design questions that need to be answered. Second, we need to know how to organize a school to take best advantage of the new technologies. What should be the role of teachers, of students, and of administrators? The second issue is by far the more difficult to solve. There are few if any analytical solutions to these issues. In general they will be solved empirically, by trial and error in settings that are as much like the real

thing as possible. In this case the "real thing" means schools. The research and development community must join in partnership with the school community to establish experimental settings where we can solve these problems. There is no way around it.

It is a realization of this need for partnership that has led us at the University of Oregon to establish the Center for Advanced Technology in Education (CATE). Through CATE we hope to bring focus to a number of activities that will provide services to schools and research and development opportunities for all in applying advanced technologies to the problems and practices of education.

2. Equity

Discussions of computers used in instruction seem to fall on both sides of the equity issue. On the negative side there is a great deal of concern about the access of women and minorities to computers. Although more boys than girls in our elementary and secondary schools will continue to seek and receive access to computers, the proportion of girls is steadily increasing. Current estimates are that a sex bias favoring boys will always exist, but it will not be as severe as it appeared it might be. Minorities are also gaining access. The main problem that is emerging from the surveys of computer uses in education is the familiar one of socioeconomic bias. The data indicate that public schools in districts with a large proportion of poor families are less likely to own microcomputers. In January 1983, two-thirds of public schools in middle- and upper-class districts had microcomputers compared with 41 percent in less-well-off districts. This sort of inequity seems likely to continue.

On the other hand, computers may offer possibilities for reducing inequity among the schools. A major problem in many states that have traditionally given little priority to education is the supply of mathematics and science teachers. For many districts in these states, it is not just a matter of there being poor mathematics and science teachers; some of these districts have no mathematics and/or science teachers at all. Computers cannot teach all things to all people, but they can teach some aspects of mathematics and science very well. In the absence of teachers, computers may reduce some of the resulting inequities in mathematics and science instruction. If teachers of mathematics and science are present but poorly prepared, computers used as tools may also help reduce inequities to a significant extent. Some states are seeking exactly these solutions to their equity problems. Whether or not Oregon will be aided by these approaches is at present hard to forecast, but results of efforts in this direction are well worth watching.

3. Software Quality

A major problem noted across the country is the lack of software quality. A recently attempted "Great American Software Contest" for instructional applications was advertised in all the major computer publications and these were folowed by more than 22,000 direct mailings. The contest attracted only 36 registrations and was cancelled. "Cottontail software" is a term used to describe the fragmentary material now at hand--it's cute, but it doesn't cover the subject. We need large, high-quality software packages that can support, for instance, all of reading comprehension for grades 3-8. One package of this sort that I am familiar with took well over one million dollars to develop and even then there was room to grow. The budget for another package to support beginning reading in grades K-2 was about $800,000. An arithmetic drill and practice program now being marketed for grades 1-6 cost over $850,000 to develop. These are all large, good quality instructional software packages and they still have plenty of room for improvement.

Where will we find the funding to support instructional software of this sort? The federal government is a possible source, but federal support for curriculum development of this sort has always been thin. Venture capital is another possibility, but right now the bandwagon seems to favor the fragmentary software packages, not full curriculum support packages. One possibility might be state support for development of high-quality software appropriate for and tailored to the needs of the state. This sort of software could support a wide range of locally specified curriculum approaches and content within subject domains--that is one of the strengths of computer-based instruction. The interesting aspect of this proposal is that the state would probably recapture its investment and generate some revenue by commissioning sales of the software and charging a royalty (maybe 6 percent) to buyers out of state. This may be an effective way to generate the software we need and computer-based instruction.

4. Software Piracy

No one will provide major financing for software development, if the resulting product is likely to be stolen. However, the schools have been ambivalent in their attitude toward piracy. On one hand they condemn the practice of indiscriminately copying and distributing protected software. On the other hand, individual schools and school users tend to look the other way when it is done for free and for their own benefit. Few of us who have built up software collections have neglected to include one or two disks with high-quality, popular, professionally developed, and protected software--but with tell-tale, hand-written labels and plain white disk envelopes.

What is to be done about this? It is simply impossible to produce disk-delivered software that cannot be copied. Software companies will not invest heavily in software that is going to be widely copied. The need to back up disks is legitimate and real--some copying must be allowed. People, especially students, will always rise to the challenges and learning opportunities of unlocking software--and computer systems in general. The software that is copied is generally not sold--there is no big-time criminal conspiracy to attack--just a lot of people nibbling the software investment to death by making single copies for their own, or their school's, use. The only solution seems to be for schools to sustain a modicum of seriousness about software piracy. We should seriously discourage it, and we should turn down offers of free, pirated software. This policy is difficult because there is no practical incentive for it other than the general good, but it should be pursued.

5. Coordination with Learning Outside of School

A major opportunity offered by the use of computers in education has always been its exportability. To some extent good teaching can be delivered to temporally and geographically dispersed students in a manner that is relatively independent of the abilities and enthusiasm of the local instructional staff. Not only can computers be used to give instruction outside of school hours, in the evenings and on weekends, but they can also be used for instruction delivered in libraries, museums, and community recreation centers. This is beginning to happen. In a state with as active a community education organization as Oregon has, we can expect it to mushroom. All this is to say nothing about the instructional software being developed for the home. At least one computer company is right now spending ten million dollars on curriculum materials to be presented on a small computer to be sold in the home market.

What if anything are the schools to do about this? Should schools compete or cooperate with this activity? Should schools offer credit for instructional material completed on computers outside of school? If school credit is offered, how should schools maintain the integrity of what is being taught? Should schools begin to pursue the notion of electronic homework, extension courses, or continuing education? One policy is to have no policy, but the schools may well want to maintain some initiative in this area.

6. Certification

If the widespread availability of microcomputers brings about a large number of self-taught, computer literate teachers, we may be faced with a classic management problem. These teachers may satisfy the current critical need for computing teachers. However, the management problem is to specify what we need before going to get it. There are likely to be many people who know a little about computers. How much do we want them to know before they start teaching students? What standards should we set for them? What certification requirements should we establish? Whatever we decide to do about quality control in this area, the time to do it is now.

Final Word

As may be evident from the preceding comments, computer-based instruction presents us all with opportunities and challenges. It will fundamentally alter what we do in education. More importantly it will most probably alter what we aim to do in education. Its main impact may be on our aspirations and expectations for our students. In any case, it does not appear that we can avoid or delay confronting these opportunities and challenges. We are all being overtaken by events. However, there is at least as much good as harm in what is happening. With some careful planning, and a little luck, we should be able to maximize the former and minimize the latter. As they say in other sectors, here is another opportunity to excell.